Transferability of monthly water balance models under changing climate conditions in an arid catchment

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SCOPE AND OBJECTIVES

Robust hydrological models should be transferable to periods with various climate conditions, regardless of the calibration period used. Here we define three hypotheses about transferable monthly water balance hydrological models:

1. **Consistency in model efficiency in the calibration and validation periods, regardless of their hydroclimatic characteristics;**
2. **Consistency in model parameters estimates; i.e., parameter estimates do not change significantly across different calibration periods;**
3. **Consistency in simulated water balance components.**

To test the formulated hypotheses, a thorough evaluation protocol of monthly water balance models' (MWBM) performance in changing climate conditions is defined. Transferability of four MWBMs, namely *abcd* (Thomas, 1981), Budyko (Zhang et al., 2008), GR2M (Mouelhi 2003, Mouelhi et al. 2006) and WASMOD (Xu 2002), is explored with proposed evaluation protocol. A challenging example of an arid catchment Wimmera in western Victoria, Australia, affected by extreme runoff decrease after 1997, is used as a case study.

EVALUATION PROTOCOL

The evaluation protocol builds on the protocol proposed by Thirel et al. (2015), where the complete record period is divided into 5 equal, non-overlapping sub-periods. The proposed protocol includes following three steps:

Step 1: Model is calibrated over 6 periods (5 sub-periods and the complete record) and validated in the remaining 5. Calibration is performed with the AMALGAM optimisation algorithm (Vrugt, 2016) and KGE as the objective function.

Step 2: Evaluation **of consistency in model efficiency, parameter estimates and simulated water balance components** in validation periods, as well as subjective assessment of model performance. Model performance is quantified by several statistical performance measures and errors in hydrological signatures calculated from simulated and observed flows. For each performance measure, the range of acceptance is defined from literature or arbitrarily. Limits of model transferability are quantified by a change in model efficiency between the calibration and a validation period relative to change in climate indices (e.g., precipitation).

Step 3: Models are ranked based on findings from the previous step and decision is made upon their transferability.

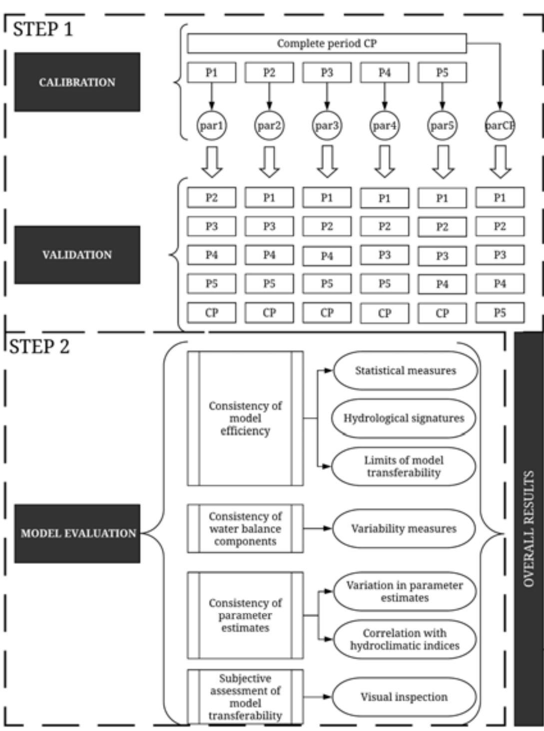

Figure 1. Model evaluation protocol (Source: Topalović et al. 2020)

RESULTS AND CONCLUSIONS

Model transferability heavily depends on the performance indicator used. All statistical performance measures are sensitive to model transfer and correspond to subjective assessment. Conversely, only few hydrological signatures are sensitive to model transfer: standard deviation, 95th flow percentile and inter-annual flow distribution. The remaining signatures are uninformative in the case of Wimmera catchment. This means that good performance in terms of statistical measures does not imply good performance in simulating hydrologic signatures because the models were not conditioned to reproduce them in calibration.

Results indicate that models should not be transferred to periods that differ by more than 15% in precipitation, relative to calibration period. Exception is the Budyko model that is fully transferable to wetter periods and the *abcd* model that is partially transferable to wetter periods (upon some, but not all efficiency measures). None of the models is transferable to the dry P5 period.

A thorough analysis of response surfaces of these two models indicates that there are parameter sets for which model performance is satisfying in all sub-periods. This means that the problem of model transferability is caused by improper calibration strategy rather than deficiencies of model structures.

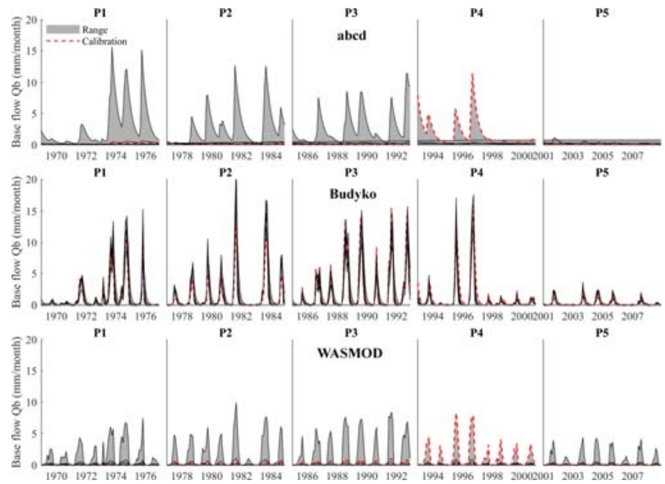

Figure 2. Simulated baseflow with parameter sets from the six calibration periods.

Simulated soil and groundwater storages and baseflow, as well as parameter estimates that control them, are the most sensitive to model transfer (especially to dry/wet transfer). No clear correlation between parameters and hydroclimatic indices in calibration period is found.

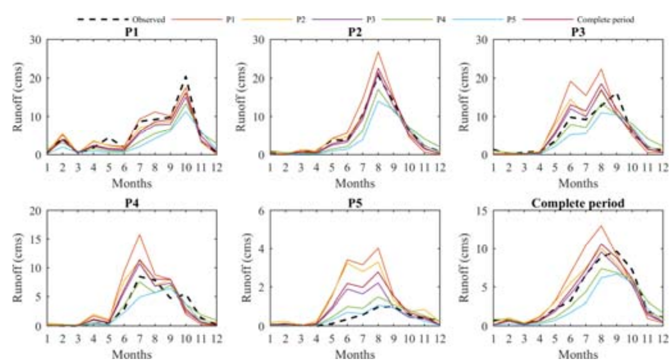

Figure 3. Inter-annual flow distribution simulated with the Budyko model

REFERENCES

Mouelhi, S., 2003. Vers une chaîne cohérente de modèles pluie-débit conceptuels globaux aux pas de temps pluriannuel, annuel, mensuel et journalier. ENGREF (AgroParisTech), Paris..

Mouelhi, S., Michel, C., Perrin, C., Andréassian, V., 2006. Stepwise development of a two-parameter monthly water balance model. J. Hydrol. 318 (1-4), 200–214.

Thirel, G., Andréassian, V., Perrin, C., Audouy, J.-N., Berthet, L., Edwards, P., Folton, N., Furusho, C., Kuentz, A., Lerat, J., Lindstrom, G., Martin, E., Mathevet, T., Merz, R., Parajka, J., Ruelland, D., Vaze, J., 2015. Hydrology under change: an evaluation protocol to investigate how hydrological models deal with changing catchments. Hydrol. Sci. J. 60, 1184–1199. doi:10. 1080/02626667. 2014. 967248

Thomas, H.A.J., 1981. Improved Methods for National Water Assessment. Water Resources Contract: WR15249270, Harvard Water Resources Group, Cambridge (MA).

Topalović, Ž., Todorović, A., Plavšić, J., 2020. Evaluating the transferability of monthly water balance models under changing climate conditions. Hydrol. Sci. J. Vol. 65 (6), 928-950. doi:10.1080/02626667.2020.1725238

Vrugt, J.A., 2016. Multi-criteria Optimization Using the AMALGAM Software Package: Theory, Concepts, and MATLAB Implementation, University of California, Irvine (CA).

Xu, C., 2002. WASMOD – The water and snow balance modeling system, in: Singh, V.P., Frevert, D.K. (Eds.), Mathematical Models of Small Watershed Hydrology and Applications. Water Resources Publications, pp. 555–590.

Zhang, L., Potter, N.J., Hickel, K., Zhang, Y., Shao, Q., 2008. Water balance modeling over variable time scales based on the Budyko framework - Model development and testing. J. Hydrol. 360, 117–131. doi:10.1016/j.jhydrol.2008.07.021